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THE DESIGN AND ANALYSIS OF HYBRID AUTOMOTIVE SUSPENSION SYSTEM

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ABSTRACT

Suspension system consists of shock absorbers and linkages used to reduce the vibrations and increasing comforts. Air bag also called air bladders are fitted into coil springs in vehicle, for better stability of ride and better comfort for passenger. This work deals with basic designing of a hybrid suspension system that was used on pick-ups. The hybrid suspension system is better as the air spring part is easily to install and cheap but it makes system more complex.

KEYWORDS: Suspension System, Automotive Design & Hybrid Systems

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Original Article

INTRODUCTION

Various sources of energy to power automotive are limited [1-3]. Automotive systems face major challenges of controlling noise and vibrations [4-11]. Suspension System supports vehicle load isolating passengers from the road disturbances. The suspension springs are capable of storing the energy as loads and deflections [11]. This energy is released back as spring comes back to original position. As this occurs the spring will undergo oscillations, contractions and extension which depends on the natural frequency of spring [12]. This work focusses on the study of a hybrid suspension system that uses air bags in conjunction with springs [13] (Figure 1). The compressed air is present in flexible bellows, made from textile-reinforced rubber. The bellows inflates raising the chassis from the axle. A combination of Hybrid airbag and coil spring suspension system is very comfortable and has ease of installation [14].

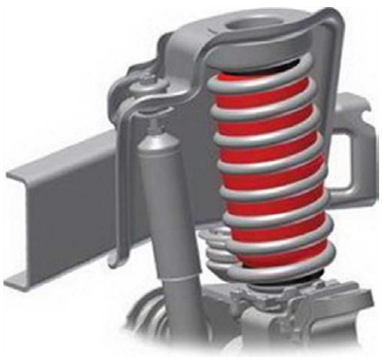

Figure 1: Hybrid Suspension System [14]

Vehicles having a hybrid suspension is often adjustable with improved handling [15-17]. It also used to support vehicle weight while loaded and continuously keep the tires in contact with the road.

LITERATURE REVIEW

Asadi et al. [18] experimentally studied and validated electromagnetic damping mechanism showing about 70% power reduction. A dynamic model for passive as well as active energy regeneration was built [19-21]. Karimi et al [22] optimized design of an air suspension system for ride height and stiffness tuning. Experimental results verified the advantages of the novel air suspension system. Bao et al. [23] used SIMULINK to calculate the stiffness and frequency of air spring suspension system using road excitation spectrum as input. Tesfay et al [24] dealt with the modelling of variable stiffness air spring for semi-active suspension system, with variable stiffness and MR damper. Roa et al. [25] designed a model in order to understand damping phenomenon in hybrid damper. Then cross checking of modeling from measurement on drop test bench was done, leading to good prediction of dynamic behavior of real system. Zou et al. [26] developed a novel hydraulic energy-regenerative shock absorber (HERSA) for vehicle suspension to regenerate the vibration energy which is dissipated by conventional viscous dampers into heat waste. Guntur et al. [27] proposed a specific design of frictional-electromagnetic-regenerative shock absorber. Based on the mathematical models, performances of the vehicle suspension and the regenerated power from regenerative shock absorber (RSA) were simulated. Ding et al.[28] modified energy-saving skyhook consisting of active control, energy regeneration, and switch. A prototype was fabricated, and a bench test was conducted. Results showed that the structure can satisfy the control requirements. Daniyan et al[29[conducted research to design an active rail car suspension system with advance control mechanism to ensure ride comfort by minimizing the effects of such disturbances or complete isolation of the car from the disturbances while enhancing increased rail way holding capacity for a variety of rail way conditions and rail car maneuvers. Patil et al. [30] designed and analyzed the semi active suspension system models using skyhook, ground hook and hybrid control method. The two degree of freedom (2 DOF) quarter car model was used for analysis of vehicle body displacement, vehicle acceleration and suspension working space and dynamic tire deflection. Simulation of semi active control models was carried out in MATLAB SIMULINK which described performance of passive system, skyhook on-off and continuous control, ground hook control and hybrid control methods. Time response analysis showed that, for road bump excitation of 70mm vertical displacement, skyhook on-off control improves ride comfort for the results of maximum peak to peak body displacement with 27.53% improvement than that of the passive suspension model [30]. Xie et al. [31] predicated numerical analysis to show that the integrated control algorithm was superior to the single controllers and was effective in improving the vehicle performance as compared with other methods. Moreover, the wavelet denoising filter was shown to be an effective way to improve the vehicle performance and enable the stability of the system against noise. Amodel to optimize the nonlinear suspension systems was used for real excitations [32]. A quarter model of an automobile having passive and semiactive suspension systems was used to develop a scheme for an optimal suspension controller [33]. Semi-active suspension was preferred over passive and active suspensions with regard to optimum performance within the constraints of weight and operational cost. A fuzzy logic controller was also incorporated into the semi-active suspension system.

DESIGN METHODOLOGY

For designing of a hybrid suspension special type Helicalcylindricalcoilspring of steelalloy (Properties Table 1) waschosen. Steel alloyisusedbecauseit has higherstrength, lowerdurability, ease of availability and is cost attractive as compared to other composite materials. Various configurations for automotive springs are shown in figure 2-4.

Table 1: Properties of Alloy Steel

Properties	Value
Tensile strength	655MPa
Yield strength	415MPa
Elastic modulus	190-210GPa
Poisson's ratio	0.27-0.30

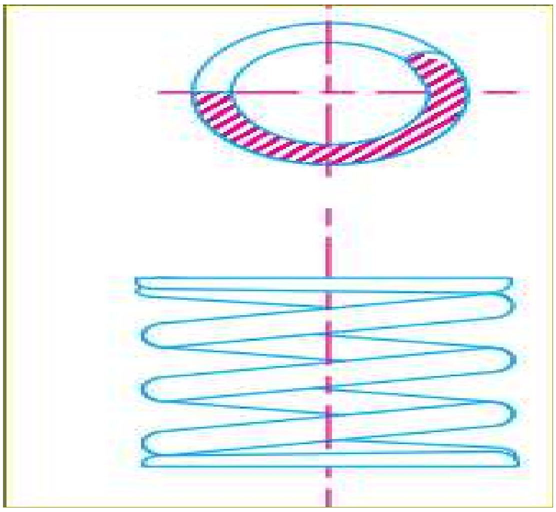

Figure 2: Square and Grounded Coil Spring

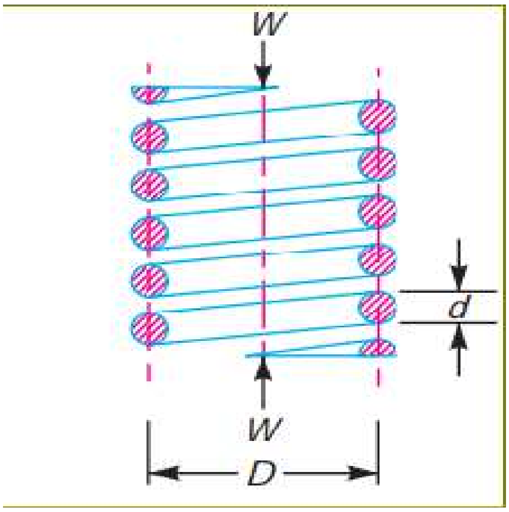

Figure 3: Loaded Spring

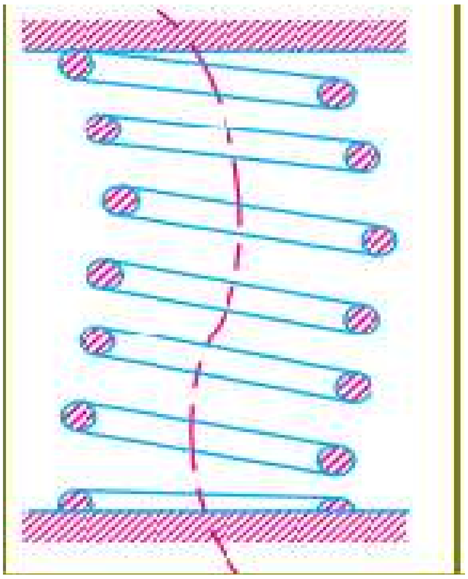

Figure 4: Buckled Spring

Boundary Conditions

The suspension system chosen for sake of analysis is a hybrid suspension system used for pick-up cars like the Toyota Hilux, ford ranger having load capacity of around 1200 kg. The spring used for design has following specifications:

- Wire diameter (d)-20mm
- Coil free height (L_f)-320mm
- Number of active Coils (n)-7
- Factor of safety (Fs)-2
- W1-1400Kg-Weight of automotive body
- W2-1500Kg -Weight to be loaded
- Free length (L_f)=p*n+2d =7*p +2(20mm) =320mm
- Pitch(p)= (320-40) mm/7 =40mm
- Solid length (Ls)= (n+2) d= (7+2)20 =180mm
- Total number of turns (n') = n+2 =9

As the weight of the car was distributed equally on the front &rear wheels, the weight on a single spring becomes: W1/4=350Kg. If the weight which is loaded to the luggage of the car is supported by the rear axle, then weight becomes: W2/2=750Kg. Hence the Total weight to be supported becomes W=350+750 =10791N

From shear stress equations we have:

$$\frac{\tau}{F_S} = \frac{8WD}{\pi d^3} + \frac{4W}{\pi d^2} \tag{1}$$

Where W=10791N

$$\tau = \frac{W}{\pi d^2}$$

From the above equation mean diameter (D) of spring was found 125.2mm. The total active length of wire is given as: π*D*n=2751mm.

The axial deflection of spring (δ) is given as: Ѳ*D/2.

Also, we know that:

$$\frac{T}{J} = \frac{G\theta}{l} \tag{2}$$

Where J is polar moment of inertia given as: $\pi/32 * d^4$

From the above equations δ is calculated as 92.66mm. The spring stiffness (K) is given as:

$$K=\frac{W}{\delta} = \frac{Gd^4}{8D^3n} = \frac{Gd}{C^3 8n} = 116\text{k N/m}$$

Considering buckling of spring we have:

Critical axial load (W_{cr})=k*K_b*L_f

Where the buckling factor (K_b) is given by ratio of L_f/D=2.55

For a square spring with grounded end $K_b=\sqrt{2.55}=0.68$

W_{cr} =116*0.68*320=2534N

As W_{cr}(2534N)>10791N

Hence design is safe from buckling.

CONCLUSIONS

As a composite material is a combination of two or more materials that results in better properties than those of individual component used alone, we conclude that the use of hybrid suspension system of a coil spring and an air spring gives the best performance than alone where the air part helps for damping vibrations that are excited due to the rod contact especially in the heavy load of the truck giving smooth ride, greatest energy dissipation, variable ride height and the coil part of the hybrid suspension has its advantage as suspension but when in combination it also helps to avoid the failure of the air spring part by reducing side swing, being irritated by external sharp materials and serves as casing holding the fittings and transport parts safely . Also, they possess significantly improved properties including high specific modulus, good wear resistance compared to individual suspensions.

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